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MINING METHODS AND COSTS IN THE WACO DISTRICT

BY

LEON M. BANKS

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MINING METHODS AND COSTS IN THE WACO DISTRICT [1]

By Leon M. Banks[2]

INTRODUCTION

The Tri-State district is well known for its prolific production of zinc. Joplin, Webb City, Galena, Baxter Springs, Picher, and Commerce are names familiar to those interested in the mining of zinc ores.

The Waco district is north of the main zinc area and not as well known as its ore bodies might justify. It is situated between the towns of Waco, Mo., and Lawton, Kans., with the Missouri-Kansas State line dividing it in two nearly equal parts. Waco is about 13 miles northwest of Joplin, Mo. The district is served by the St. Louis - San Francisco, Kansas City Southern, and the Joplin and Pittsburg railroads. A concrete highway passes within 2 miles of the center of the district.

The topography is that of slightly rolling prairie land. The mines have all been developed on previously existing farms, and the workmen are native Americans who live on the surrounding farms or in the numerous towns within a radius of 15 miles.

HISTORY

The mines were first opened in 1917 and have produced continuously since. Shallow ore was first discovered and worked. Progressively deeper drilling then opened up the upper ground, and finally mining was carried down to the 300-foot level or lower ground.

The following companies own leases or fees in the district: St. Louis Smelting and Refining Co., a subsidiary of the National Lead Co.; American Zinc Lead and Smelting Co.; Missouri Mining Co., a subsidiary of the Consolidated Gold-fields of South Africa; Universal Exploration Co., a subsidiary of the U. S. Steel Corporation; Kansas Exploration Co., a subsidiary of the St. Joseph Lead Co.; and, the Missouri-Kansas Zinc Corporation, a recent consolidation of the Butte-Kansas, Acme, and Barnsdall Mining companies.

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2 One of the consulting engineers, U. S. Bureau of Mines.

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The district had produced 298,376 tons of zinc concentrates of a gross value of $12,769,548 and 2,377 tons of lead concentrates of a gross value of $191,020 up to the end of 1928.

This paper will describe the operations of the Acme mine of the Missouri-Kansas Zinc Corporation.

GEOLOGY

The surface formations underlying the district are the Cherokee shales of the Pennsylvanian and the Boone formation of the Mississippian period. The Cherokee shale has an average thickness of 40 to 60 feet over most of the district but is eroded away in places towards the east and south. The upper part of the Boone formation is limestone and contains a bed locally named the Short Creek oolite, which is not always present in this field. Near the middle of the Boone formation occurs the Grand Falls chert, a massive bedded chert, the "sheet-ground" formation of Webb City and Baxter Springs. Below the Grand Falls occurs the "second lime" or dolomite.

Details of general geology may be obtained from Folio 148, United States Geological Survey, entitled "Joplin District Folio, Missouri-Kansas," by W. S. T. Smith and C. E. Siebenthal.

ORE DEPOSITS

There are from two to four ore horizons in the Waco district. The upper horizons are 100 to 165 feet and 165 to 200 feet below the surface and lie above the Grand Falls chert bed. The lower horizons are at the 230 to 250 foot and the 270 to 300 foot levels from the surface and below the Grand Falls chert. The two upper horizons are merged together by chimneys of ore in some places, as is also true of the two lower horizons.

Structural synclines have been formed by the caving of solution caverns in the limestones and dolomites. There has been an infiltration of the overlying shales in this caved breccia and a silicification in the form of flint. The economic mineral is sphalerite, which occurs in crystalline form as a part of the breccia filling. The upper horizon ores are thus a mixture of flint, shale, and some limestone or dolomite; the mineral is mainly "free ore."

Beneath these structural synclines or "shale slumps" the heavy bedded Grand Falls chert and the lower limestone beds have been fractured and displaced but not to the same extent as the overlying beds. They have adjusted their internal stresses by bending and block-faulting on a small scale. The mineral occurs in the cracks and bedding planes of the fractured beds and is also finely disseminated in some dolomite beds. Because of this dissemination the ores below the Grand Falls chert require finer grinding to liberate the mineral and are known as "chatty ores." Less flint is present, and shale is practically absent in the lower ores.

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Very little galena or other forms of lead are found in these mines. The zinc concentrates usually contain less than 0.10 per cent lead and command a premium above prime western prices because they are lead-free.

As a rule the ore beds are horizontal, but there is some folding and distortion near the major fractures. Ore faces vary from 8 to 100 feet in height. The ore commonly follows fracture lines and sometimes spreads out over large areas where intersecting fracture zones form favorable conditions for ore deposition. The genesis of the ore is a matter of dispute.

Mill recoveries run 3½ per cent blende and upward. The average for the field has probably exceeded 6 per cent blende.

EXPLORATION

The existence of ore was discovered by churn drilling. Development is planned and mining is guided by the evidence revealed by the churn drills. Holes are started with a 6¾-inch bit and drilled without casing at a prevailing rate of $1 per foot. Cuttings for samples are taken at each 5 feet of hole.

Some companies make a practice of "shale-drilling;" that is, the depth of the bottom of the Cherokee shale bed is determined, and when it is found to be in the normal position, drilling is stopped on that hole. When deep shale is encountered, indicating the presence of a sump or a structural syncline, the drilling is continued to depths of 280 to 350 feet.

The first drilling on a new piece of ground is on a hit-or-miss basis. After ore has been found, it is followed and delimited by closer spacing of the holes. Recent practice has been to drill on cross-section lines normal to the known trend of the ore-runs.

On the property of the Missouri-Kansas Zinc Corporation 640 holes with a total footage of 151,352 feet have been drilled.

Underground churn-drilling has been done when the overlying surface was inaccessible because of water ponds, slime ponds, tailing piles, or other obstacles. The average cost of underground drilling has been $1.923 per foot.

Deep-hole drilling or prospecting with heavy hammer drills having independent rotation has been used extensively in the mines of this company. This drilling has cost $0.644 per foot. The cuttings were found to be useful as indications of the presence of mineral but proved unreliable when assayed for grade determinations.

Where the ore beds have dipped below the floor of the working levels, piston drills have been used to prospect to a depth of about 17 feet. This has been done at a cost of $0.573 per foot. When careful cleaning around the collar of the hole had been done before drilling, the samples were found to be fairly reliable.

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Geophysical or electrical methods of prospecting have not been tried in the district.

SAMPLING AND ESTIMATION OF TONNAGES

Channel or grab sampling in the mine is not practiced. Ore-reserve calculations are based on study of churn-drill logs. Control of mill feed is guided by visual sampling and mill recoveries.

DEVELOPMENT

Ore bodies, after discovery by churn-drilling, are developed by means of vertical shafts sunk to the level of the ore, as indicated by the drill logs. Some companies sink the first or mill shaft in the heart of the best ore holes. Others sink at one side or at least in the poorer parts of the ore body to avoid leaving large amounts of ore in shaft pillars. In the former case, mining can commence as soon as the ore is reached. But in the latter it is necessary to drive a "pull-drift" from the shaft to the ore body before mining can begin. In nearly all cases more than one shaft is sunk on the same ore body or on separate bodies so that more points of attack are presented. This also provides additiona hopper capacity and a means of ventilation. Haulage from the "field shafts" to the mill incline is on the surface by means of steam or gasoline locomotives pulling trains of 2-ton end-dump cars.

Both mill and field shafts are usually 5 by 7 feet in the clear. They ar timbered through the surface material and shale beds by a cribbing made of 2 by 4 inch timber laid flat. These timbers are nailed at the corners and to fillers in the center. No timbering is used through the hard beds unless a fractured zone is encountered. The work is usually done on contract. Two or three shifts may be worked and the best accepted practice is for each shift to drill, blast, and muck a round. Figures 1 and 2 show the shaft rounds used. The numbers indicate the order of firing. Figure 1 shows a round, requiring 40 sticks of 30 per cent gelatin to pull 3 feet; the round can be drilled, blasted, and mucked in an 8-hour shift. Figure 2 shows a round for use in harder ground, requiring 50 sticks of 30 per cent gelatin. Drilling is done with drills of the jackhammer type using hexagonal steel of 7/8 and 1 inch size having a double-taper cross bit. Holes a loaded with 30 per cent gelatin and detonated by means of waterproof fuse and 6 caps. Broken muck is loaded into cans by hand shoveling.

Stations are cut at the different horizons indicated as having ore. Ho ing from one level only is customary, but conditions sometimes require hoisting from more than one level; however, this results in lowering the tonnage a given hoist can handle, because of the delays incident to changing from one level to another. Stations are cut wide enough to allow room for landing the empty can one side and to permit the hooker to keep from under the shaft. The station is just high enough to allow handling of long steel and rails. Stations are usual untimbered.

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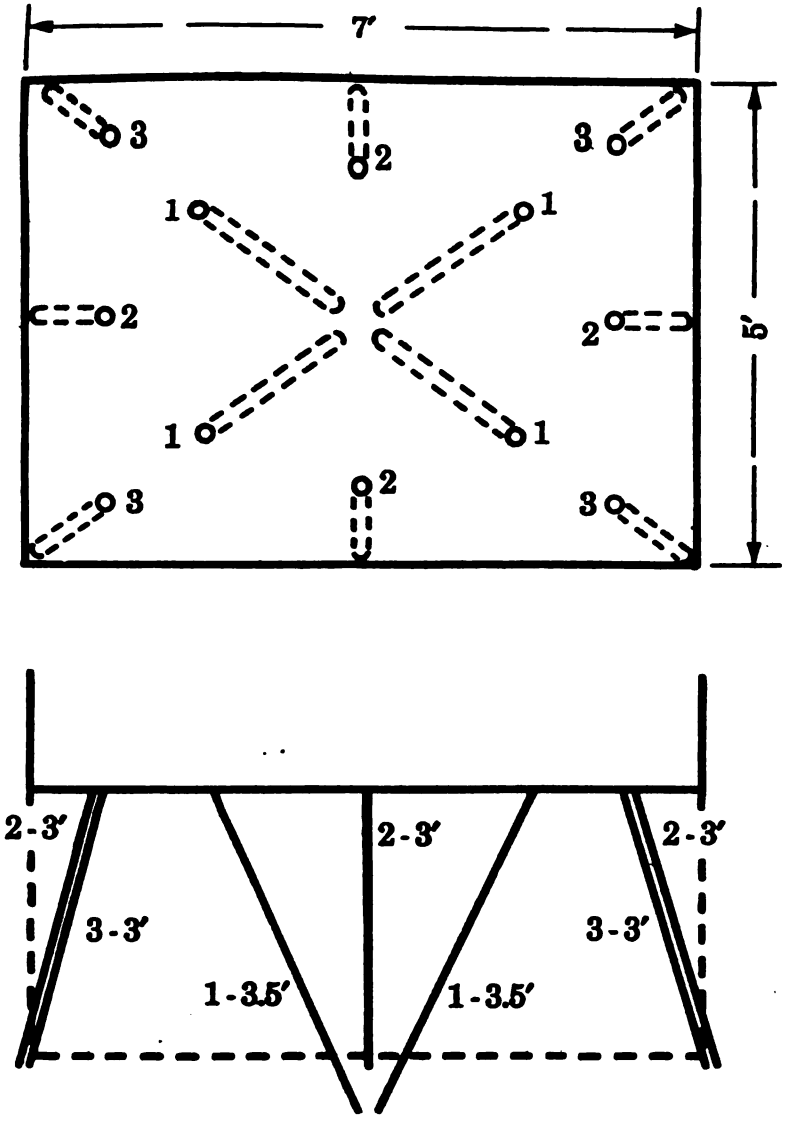

Figure 1.— Twelve-hole shaft round

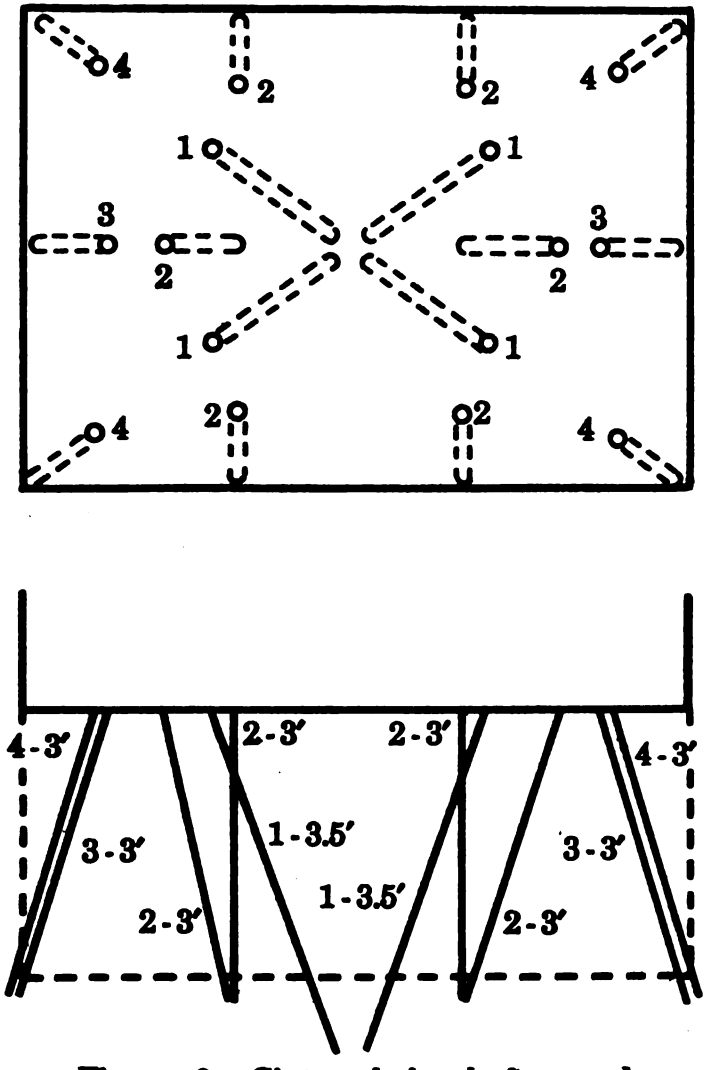

Figure 2.— Sixteen-hole shaft round

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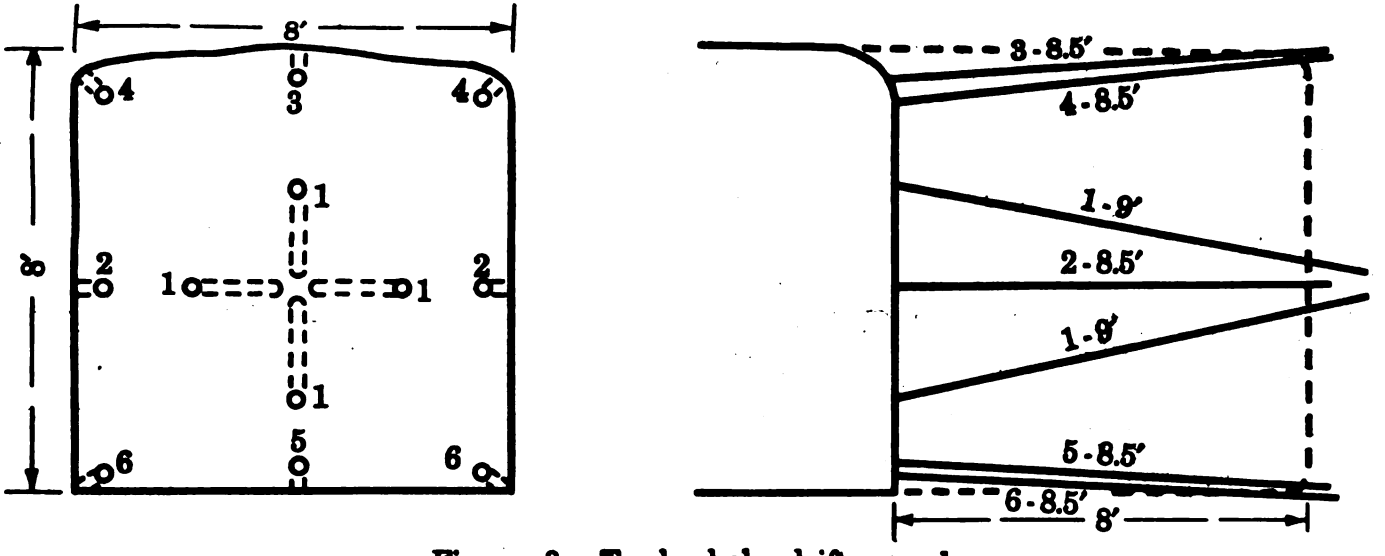

Figure 3.— Twelve-hole drift round

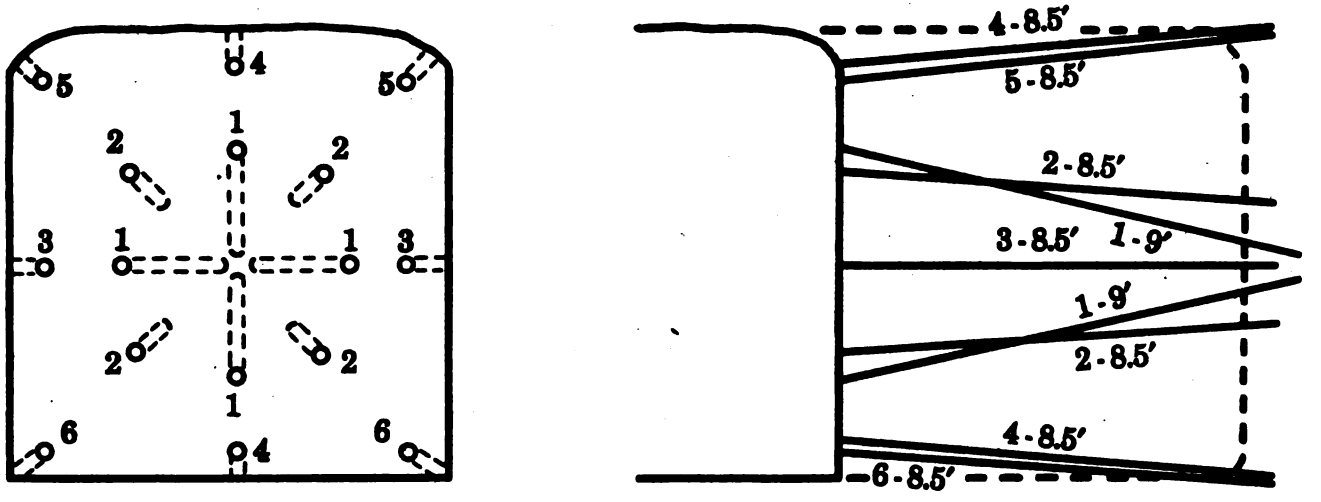

Figure 4.— Sixteen-hole drift round

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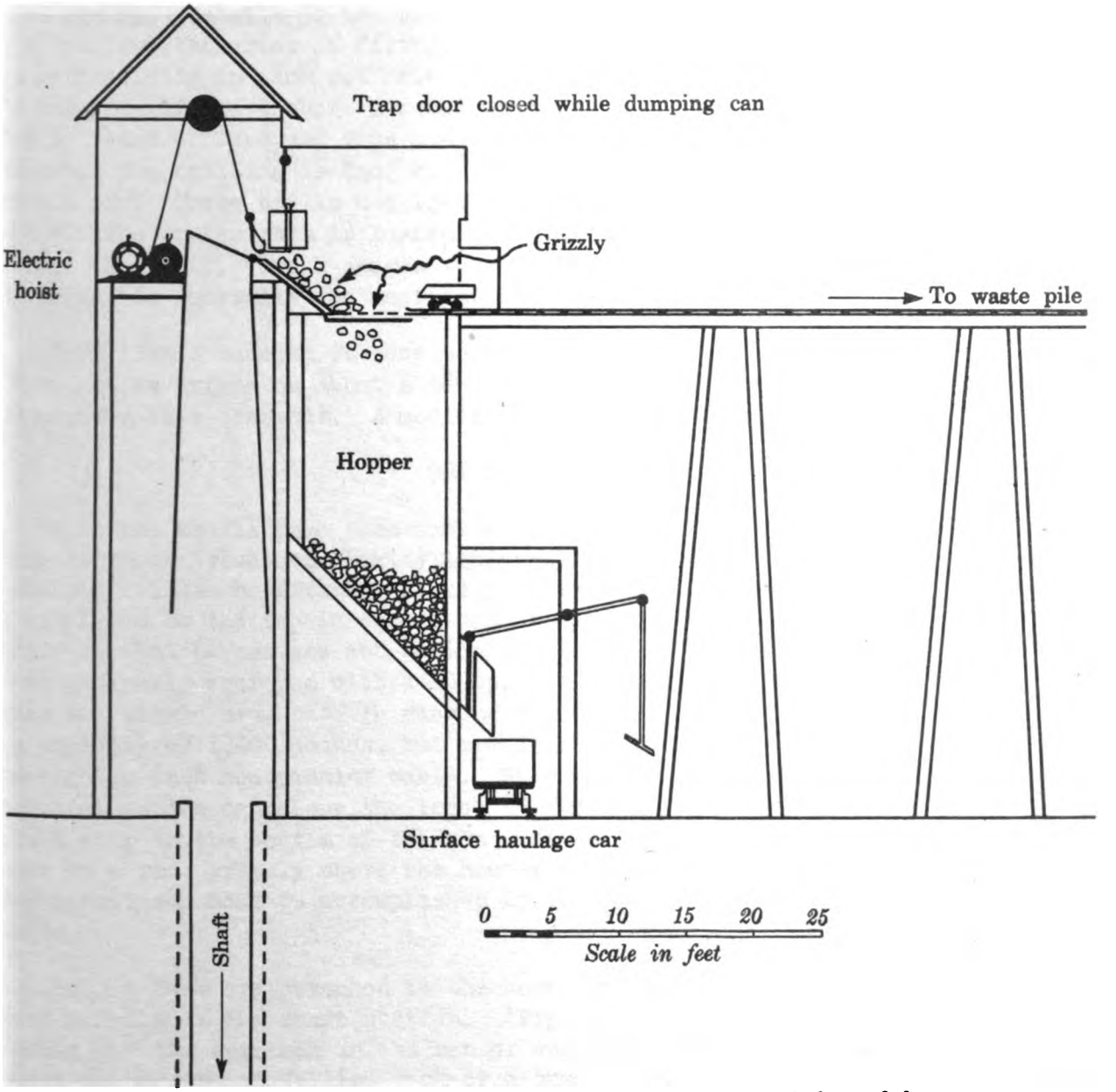

Figure 5.– Hoisting equipment, showing headframe, hoist, grizzly and hopper

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A pull drift, 8 by 8 feet, is driven from the shaft to the ore for haulage purposes. The width is sufficient to permit lay-bys or sidetracks to be placed on the haulage road wherever desired. Pull drifts are untimbered except in fractured or caved ground. Details of the rounds used are shown in Figures 3 and 4. Numbers indicate the order of firing. Fig. 3 shows a round requiring 12 sticks of 30 per cent gelatin in each cut hole and 12 to 14 sticks of 20 per cent pulp powder in the others. Figure 4 shows a round employed in harder ground. The powder is blasted by means of fuse and caps and the holes are fired in the order shown in the sketch. The drilling is done with heavy Leyner-type hammer drills mounted on column and arm. These drills use 1¼-inch round, hollow steel with a double-tapered cross bit. The broken rock is loaded into cans set on ground-cars, and hand-trammed to the shaft. Track gauges vary from 12 to 24 inches in different mines but 18 inches is generally the most satisfactory.

Very little raising is necessary in these mines. When a raise is necessary, it is driven on about a 45° inclination by means of the Leyner-type drills mounted on a crossbar. A modification of the drift round is used.

ORE MINING

When the shafts have been sunk and the pull drifts extended to the ore, the temporary headframe and sinking equipment is removed, and permanent equipment is installed. These headframes, locally called derricks, are so built that the hoist is placed at the top in such a manner that the hoistman is at the side of the shaft so that he can see and feel what is taking place in it (fig. 5). The hoist is generally equipped with a 75-hp. low-voltage electric motor which operates the single drum through gearing and a band-friction clutch. The cans have a capacity of 1,400 pounds, but are loaded to 1,200 pounds and are hooked on a five-eighths-inch nonspinning cable. No guides or crossheads are used. The hoistman raises the can above the level of the dumping apron, attaches the dumping hook to a ring in the bottom of the can, and the can is then lowered to dump the contents on a rail grizzly above the hopper or bin. The operation of the hoist, dumping apron, and hook is accomplished by the hoistman without moving from his controls.

Loaded cans are attached to the hook, and the empties are removed by a "hooker" working in the shaft station. (Fig. 10.) No signals are used between the hooker and the hoistman unless men or supplies are being handled. The hoistman warns the hooker of falling rock or a bumping can by extinguishing the station lights. The hooker is stationed at the side of the shaft on a platform of the same height as the ground-cars. While the loaded can is being hoisted he rolls the empty can from his platform to a ground car, and a helper known as a "bumper" then trams it to the lay-by for empties. The bumper then places a loaded can in position for the hooker.

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Trains of five or six loaded cans are hauled by mules to the shaft lay-by and the empties returned to lay-bys near the shovelers in the working faces (fig. 10). Main haulage tracks are made of 12-pound rail spiked to 3 by 4 inch oak ties. Various gauges have been used, as noted above, but 18 inch has been found to be most satisfactory. Lighter rails, 8-pound, are used for the tracks extending into the working faces. A typical haulage lay-out is shown in Figure 6.

The mining method is one of open stopes, with pillar support, as shown in Figures 6 and 7. The pull drift from the shaft is enlarged when it reaches the ore and becomes a mine-drift Figure 8 shows the method of advancing the heading and stope. These drifts are carried from 40 to 60 feet wide with a height that is dependent on the height of the ore above the mining level. This height may vary from 8 feet to more than 100 feet. The size of these drifts and of the pillars is governed entirely by local ground conditions such as height of face, character of the roof, character of the material being mined and that left in the pillars, distance from the surface, overlying beds, and other variable factors. Bowldery ground with fractured or shale roof requires small drifts and large pillars, whereas hard ore with lime or flint roof permits larger drifts. It is necessary to leave a shell of roof ore under shale to lessen the danger of roof-caving. Upper-level workings under shale roof easily funnel through to the surface even when only a small area is exposed.

As has been stated, the size and location of the pillars, which contain from 15 to 40 per cent of the ore (fig. 6), is governed by ground conditions. It is good practice to leave large pillars on the first cut through an ore body, and to place them in the poorer ore when possible. The habit of leaving large pillar is not done for safety only, but because it furnishes a quickly available reserve of easily mined ore when needed. The mining methods in vogue in the district do not permit any ore storage between mine and mill except the limited amount in the surface hoppers. Hence it is desirable to have a quickly available source of ore when unforeseen events suddenly cut off the supply from the regular places. Trimming or crosscutting of large pillars serves this purpose. Pillar ore can also be used to mix with ore from the faces or drifts to maintain a desired grad of mill feed.

The mine drifts are advanced by carrying a 10 to 12 foot heading at the top and keeping it ahead of the remainder of the drift. Holes are drilled by heavy Leyner-type drills mounted on column or tripod, and the face is cut out by horizontal drill-cut rounds. Details of the rounds are shown in Figure 8, in which holes 1 to 5 are the heading round, holes 6 to 14 are splitters, and holes 15 to 17 are stope holes. These rounds are drilled from 10 to 14 feet deep and are charged with "bulk" powders of 15 to 25 per cent grades. The charge is tamp with cartridges filled with flotation tailings. Taped fuse and 6X caps serve f detonation of the charge. No squibbing or chambering is needed. As the headin is advanced, a bench is left between the haulage level and the floor of the hea ing. This is drilled with long, nearly horizontal holes 14 to 20 feet deep. T same machines used in the heading, but mounted on tripods, drill these holes.

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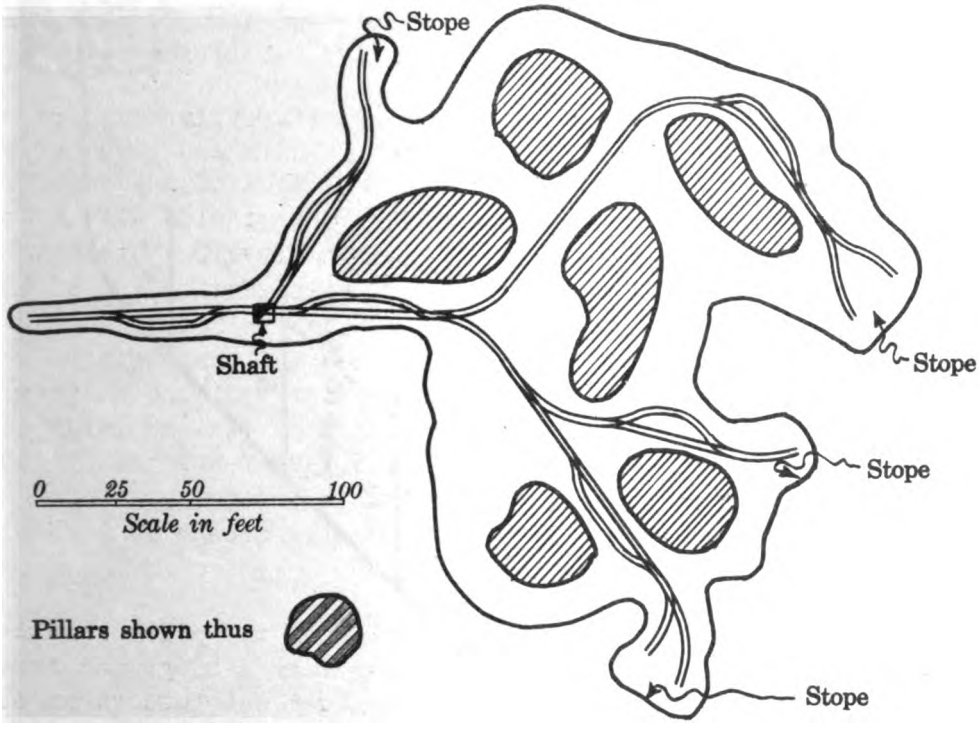

Figure 6.– Plan of haulage system

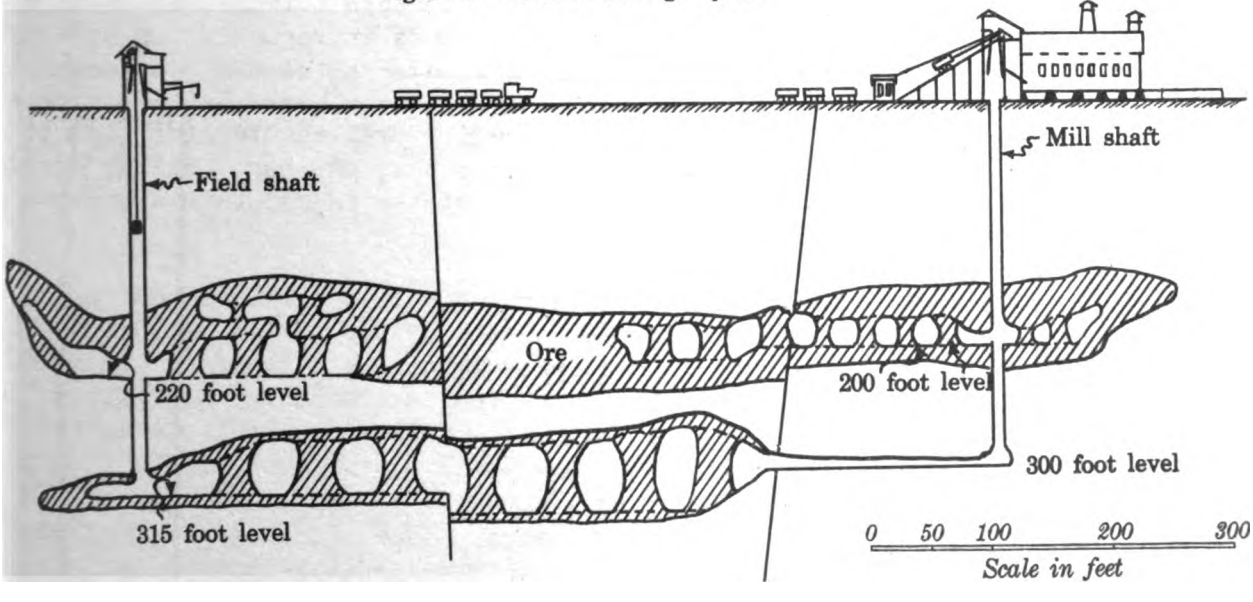

Figure 7.– Ideal section showing shafts, mine levels and displacement of ore

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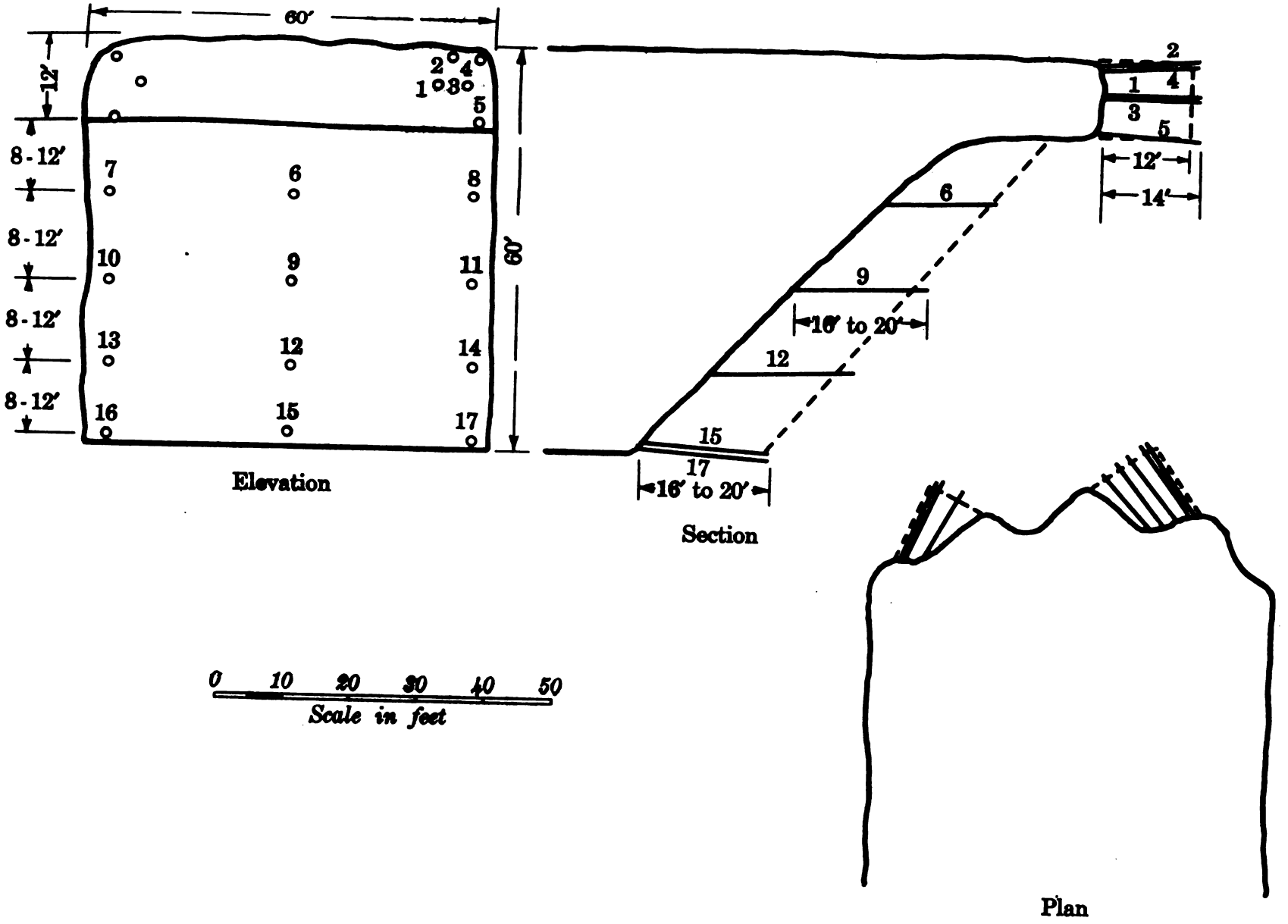

Figure 8.— Details of mine drift, showing method of advancing heading

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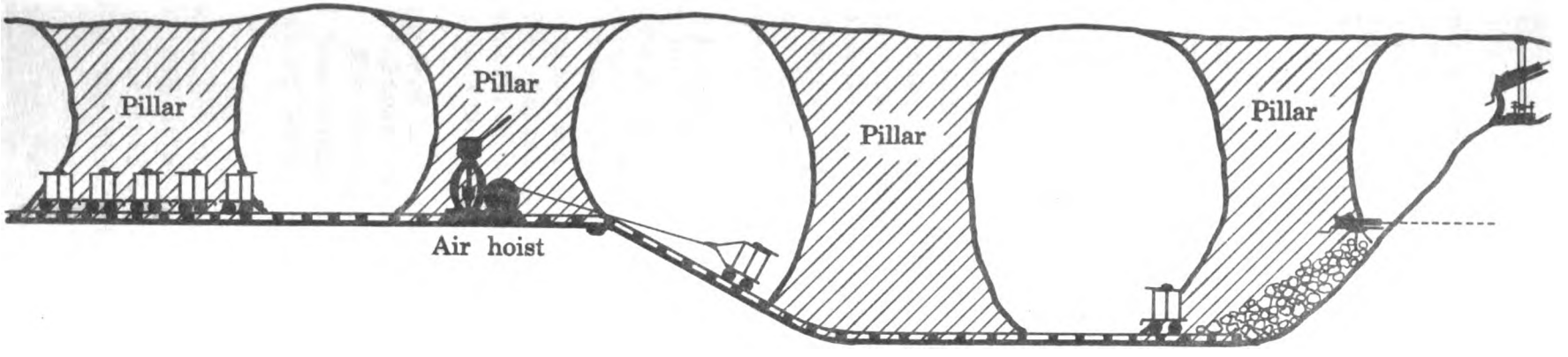

Figure 9.– Mining method used when ore is below haulage level

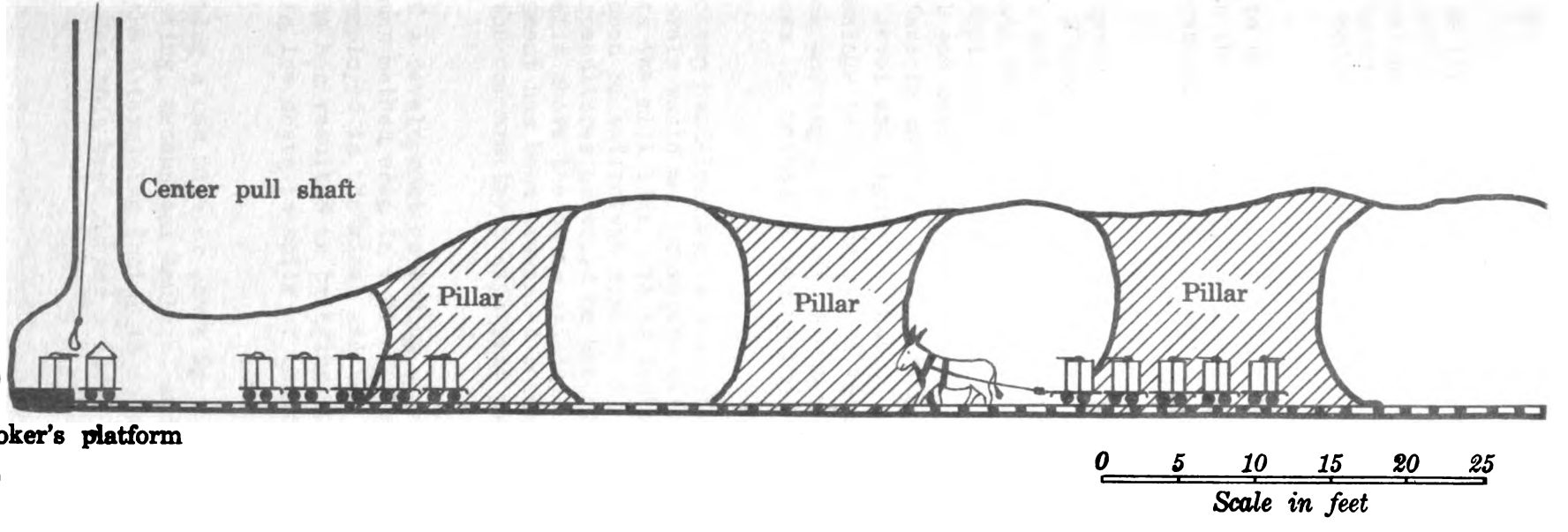

Figure 10.– Section showing shaft, hooker's platform and haulage level

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floor holes are known as "stope holes" while the intermediate ones are called "splitters". The fractured condition of much of the ground makes the drilling of down holes difficult because of excessive caving, and it has become standard practice to drill nearly horizontal holes to avoid delays due to cleaning caving holes. Better breaking is obtained in the bedded ores with horizontal holes than with vertical holes.

Two men are employed on a machine to do the drilling and the pipe work. Other men, known as roof-trimmers, bar down the loose rock, lay track, and load the holes drilled by the machinemen. All underground labor, except that performed by shovelers, is on company account.

All loading of cans, except from hopper workings, is done by hand-shovelers working on contract. Oak planks 2 inches thick are used for shoveling platforms. A lay-by is kept near the face, and the shoveler obtains his empty can from it and returns the load to it. Hand-shoveling is being eliminated in many mines of the world but has not been displaced here. Mechanical shoveling has been tried - in fact one type of air shovel was developed in one of the mines of the district - but it has not proved satisfactory under local conditions. Figure 9 shows the method of reaching ore below the level and Figure 12 that of recovering ore from runs above the elevation of the haulage level by driving a raise and installing a hopper. Figure 10 is a section showing the shaft, the hooker's platform, and the haulage level. Figure 11 shows the method of mining the ore horizon above the haulage level.

Local labor is very efficient and cheap hand-loading is available. The use of any of the recognized types of power shovels would mean complete alteration of methods and equipment from the mine faces to the mill bins. It is doubtful whether or not any of the ore bodies have been of sufficient size to allow for amortization of capital involved in such expenditures as would be needed to mechanize the mines and still show much profit above the costs obtained by hand-shoveling. The introduction of such equipment has been prevented because of the size and irregularity of the deposits and the comparatively high initial cost of such an installation.

The present method is the result of a development extending over the entire life of the Tri-State field and is the common method used in most of the mines of the district. The character of the labor employed in the mines and the long experience of the workmen with these methods has resulted in bringing the methods to a high point of efficiency with resulting low costs in spite of their apparent crudeness.

The economic risk involved in starting a new mine or shaft by these methods is much lower than it would be if skip-hoisting, mecahnical haulage, and power shovels were used; this has probably been the determining factor in opening most of the mines of the district. When a mine has thus been opened and a large ore body is

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developed, the added cost of changing methods and educating workmen to other methods has been more than most managements cared to attempt.

Natural ventilation is sufficient for most of the workings because of their shallow depth and the numerous shafts that are soon connected together by mine drifts. Dead headings are ventilated by small fans and collapsible tubing or by drilling a churn-drill hole into the heading and setting a small blowing fan on the hole.

Few underground fire hazards exist. Very little timber is used except for cribbing in the shafts, and these are usually wet enough to lessen the danger of fire. Mule barns and pump stations hold a strictly local hazard. No special organization is maintained for fire-fighting or mine-rescue work.

Safety of the mine workings is entrusted to the ground-bosses, who receive a bonus of $7.50 for every 500 shifts worked under them without a lost-time accident. Special men are employed for roof-trimming and handling powder, which reduces the hazards of such work. Hookers wear steel helmets for protection against falling objects. Most of the workmen have been trained in first-aid work by the Bureau of Mines.

Illumination of the higher faces is obtained by the use of electric flood lights. Large portable carbide lights are used by the roof-trimmers when barring down. Shaft stations and haulageways are lighted by electricity.

Pumping duty is comparatively light. The Missouri-Kansas company is handling about 1,000 to 2,500 gallons per minute from its four mines. The amount varies with the season as the numerous surface caves allow rain water an easy access into the mines. Triplex pumps and centrifugal pumps of various sizes are in use and work against a head of 300 to 310 feet.

Underground wages are based on an eight-hour shift and a sliding scale dependent on the Joplin concentrate market. When 60 per cent zinc concentrates are selling for $40, the following scale is in effect:

Machinemen	$3.50
Machine helpers	3.00
Powdermen - roof trimmers	4.00
Hoistmen	3.75 - $4.25
Hookers	3.75 - 4.25
Bumpers	3.25
Mule skinners	3.50
Shovelers (contract) ...	.09½ cents per can. (1,200 lbs.)
Ground bosses	40.00 per week

Shaft-sinking, raising, and drifting are done on a contract basis with t contractor furnishing explosives and all labor involved. Equipment, sharpening, air, and timber are furnished by the company.

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Shafts are contracted at $10 per foot.

Drifts run from $6 to $8 per foot.

Raise contracts average about $5 per foot.

The duty of a machine in a heading averages 30 to 40 tons per shift, while one in stoping averages 80 to 100 tons per shift or an average total for the period of 62 tons per machine shift.

The steel consumption per ton of ore mined is .0207 pounds per ton.

The standard cans are 32 inches in diameter and 30 inches high. Their capacity is 1,400 pounds, but they are loaded to 1,200 pounds.

Pulp powder costs $14 per hundred; 20 per cent gelatin, $12.25; 30 per cent gelatine, $12.50; caps, $1.24 per 100; and fuse, 63 cents per 100 feet.

MINING COSTS

The following table gives the cost of delivering a ton of ore to the mill bins of the Acme mine of the Missouri-Kansas Zinc Corporation. This includes surface transportation from field shafts, steel sharpening, compressed air, hoisting, and breaking bowlders through the mill grizzly, as well as all underground costs. The period covered is from May 11, 1927, to January 2, 1929. During this period 364,285 tons was hoisted.

Mining Cost Per Ton of Ore Delivered to Mill Bin

	Labor	Supervision	Electric power	Explosives[1]	Other supplies[2]	Total
Mining[3]	$0.310	$0.044	$0.072	$0.072	$0.042	$0.540
Underground haulage	.050	.007	- -	- -	.007	.064
Hoisting	.062	.009	.012	- -	.008	.091
Pumping	.013	.002	.017	- -	.004	.036
Surface haulage	.019	.003	.008	- -	.003	.033
General	.015	.002	- -	- -	.004	.021
Total	0.469	4/0.067	5/0.109	0.072	0.068	0.785

1 Caps and fuse included.
2 Timber included.
3 Mining and development combined.
4 Includes prorata of manager, assistant, superintendent, etc.
5 Compressor power included.

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Summary of Costs in Units of Labor, Power, and Supplies

Tons of ore mined and hoisted: 364,285. Period covered - Years 1927-1928.

Mining method: Open stopes with pillar support.

A. Labor:	Man hours per ton
Breaking (drilling and blasting)	0.2799
Mucking	.3547
Haulage and hoisting	.3672
Pumping	.0131
Supervision	.0264
Total labor underground	1.0413
Average tons per man shift	7.68
Labor, percentage of total cost	60.06

B. Power and Supplies:	
Explosives (lbs. per ton)	0.594
Total power (in hp.-hrs. per ton)	6.651
Other supplies in percentage of total supplies and power	27.31
Supplies, percentage of total cost	39.94

Note: Mining and development charges were not kept separate during most of the period.

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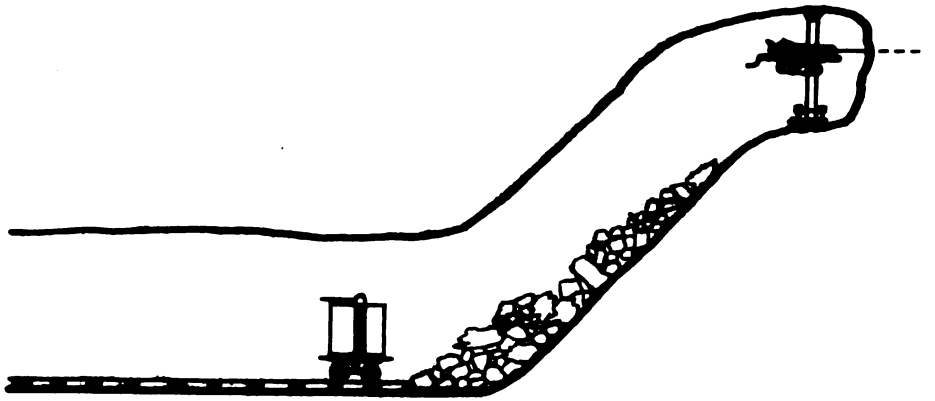

Figure 11.– Method of mining ore horizon above haulage level

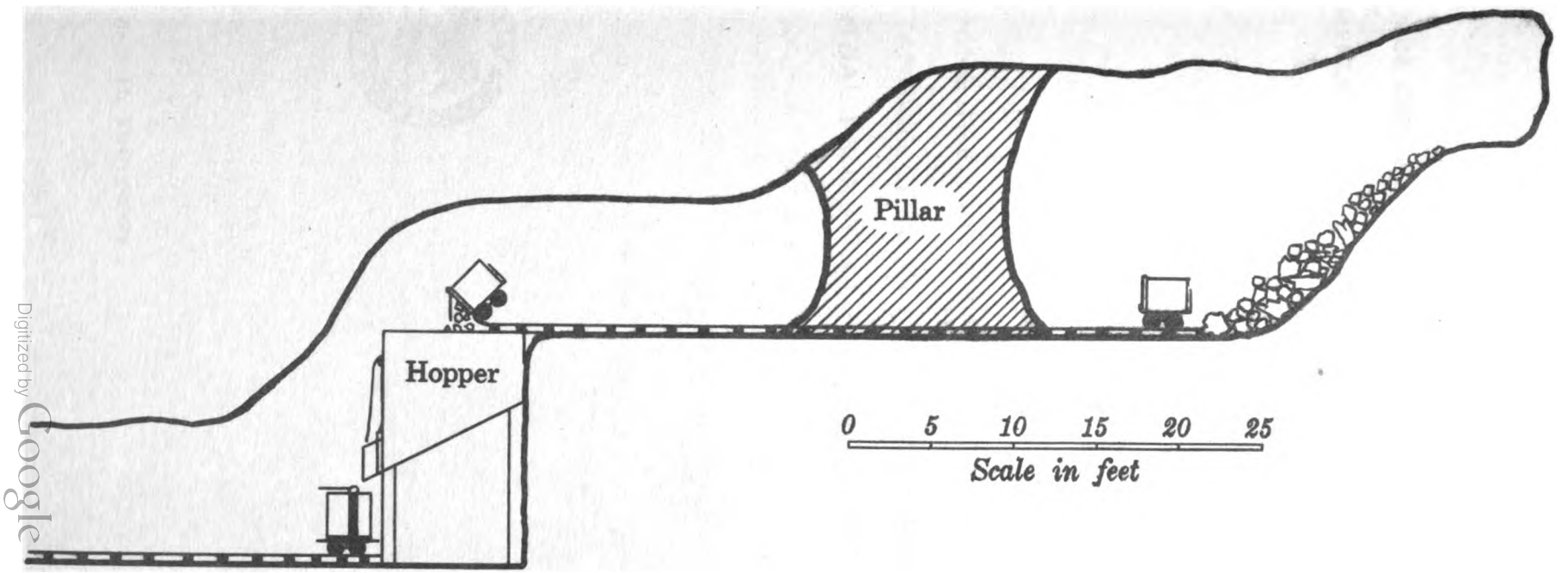

Figure 12.– Use of underground hopper

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